Design of a sample approach mechanism for a metrological AFM

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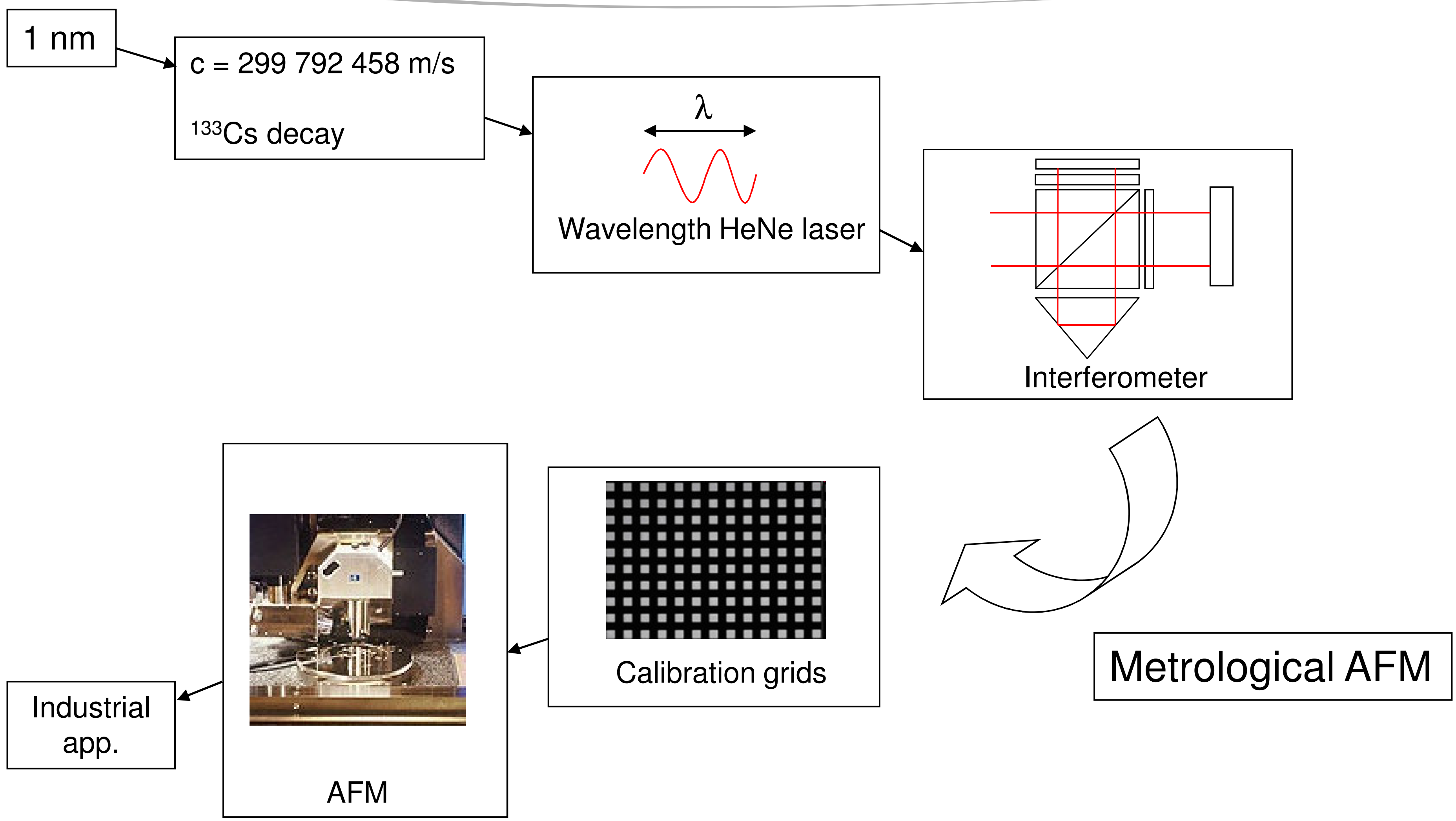
Overview

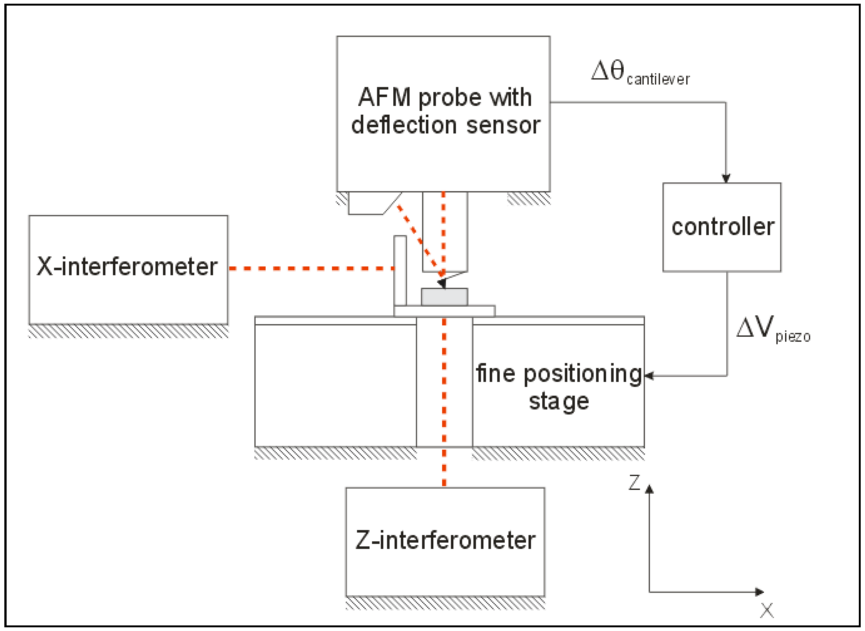
- Introduction
- General layout metrological AFM
- Design sample approach mechanism
- Experimental results
- Simulation
- Conclusions

Introduction



Introduction

- Three orthogonal interferometers
- Nanostage scans in XY-plane
- AFM-probe detects deflection
- Nanostage zeroes signal
- Map of Z as function of X and Y



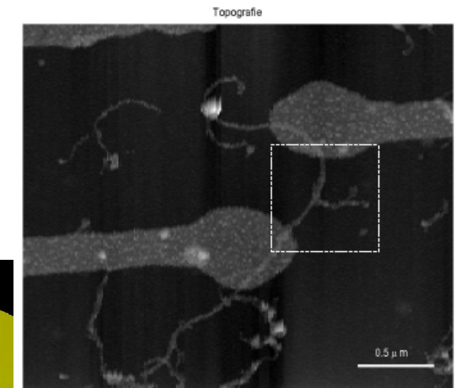
<u>Advantages:</u>

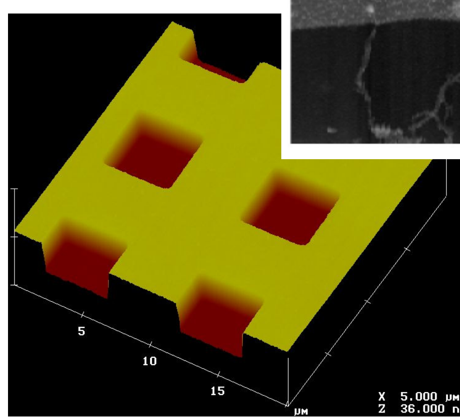
- Directly traceable measurements
- Measures local values

Introduction

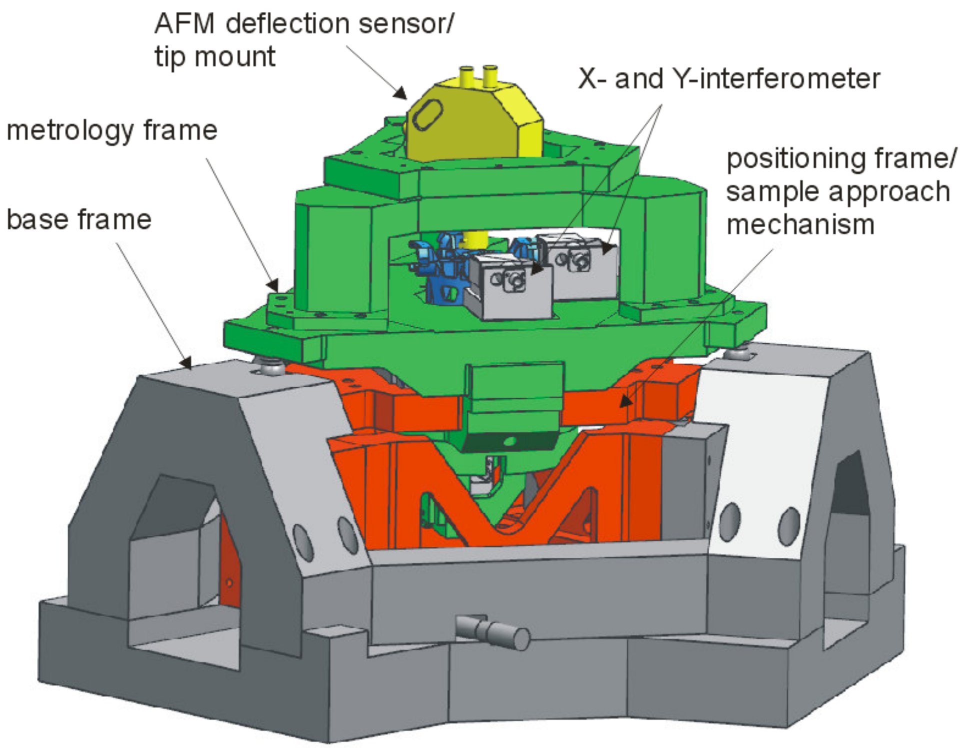
Project goal

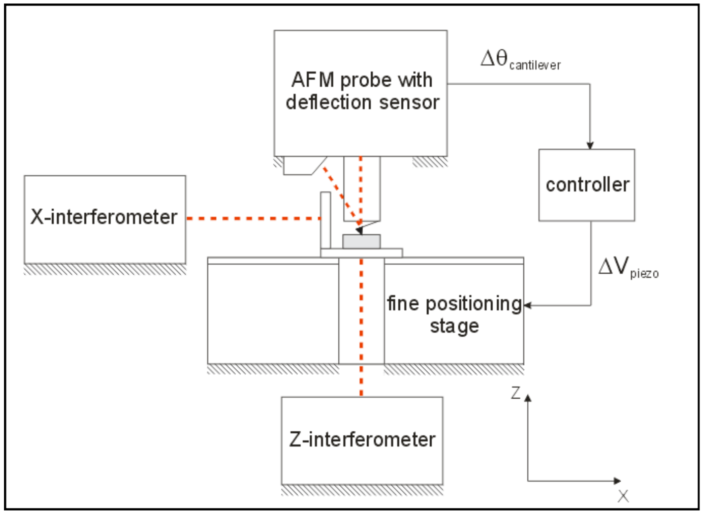
- Calibration device for traceable measurements
- Designed for FPS Economy, SMEs, Self-employed and Energy
- Specifications:
  - ✓ 1 nm accuracy
  - ✓ stroke of 100 µm x 100 µm x 100 µm
  - ✓ calibration nanogrids
  - ✓ direct measurements





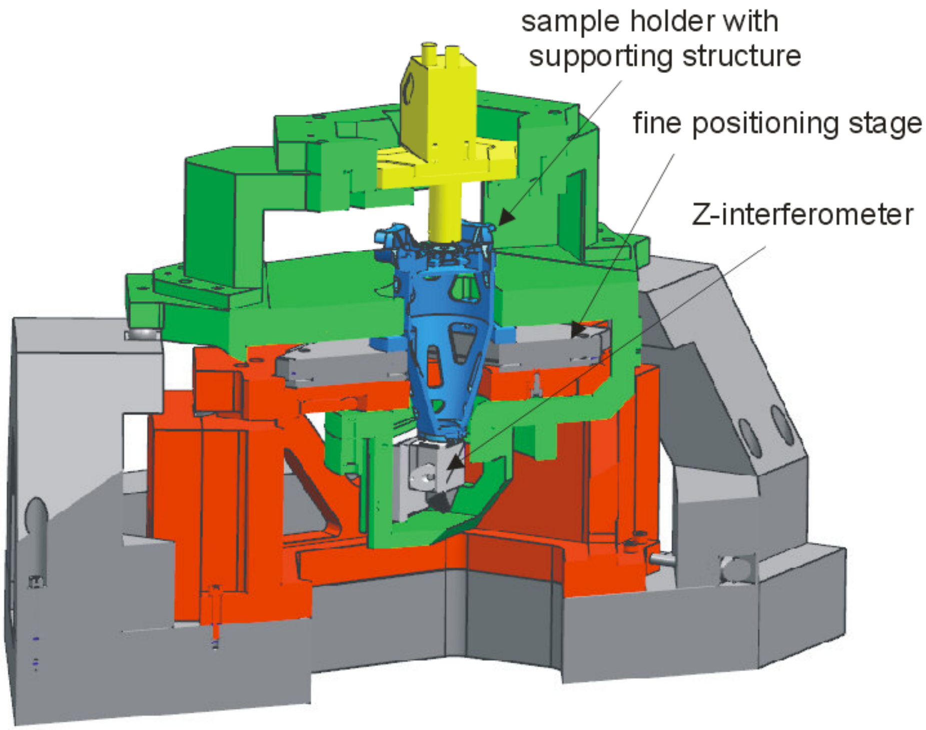
General layout: frame

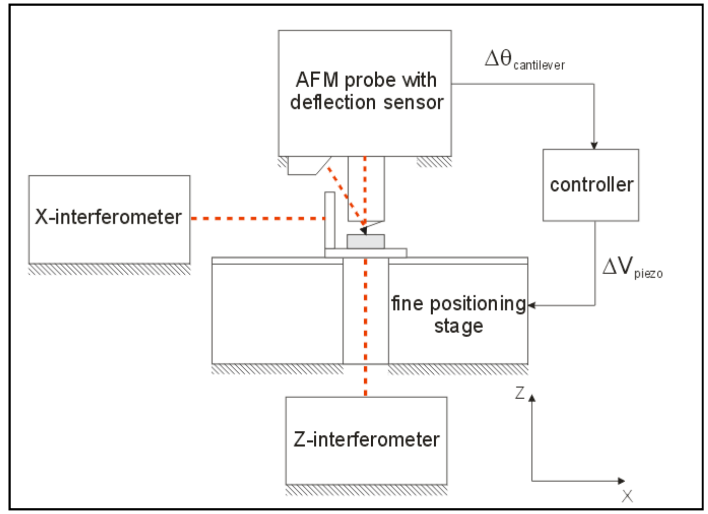




- Materials choice for minimum thermal drift
- Thermal conductivity
- Separated force loop

General layout: frame





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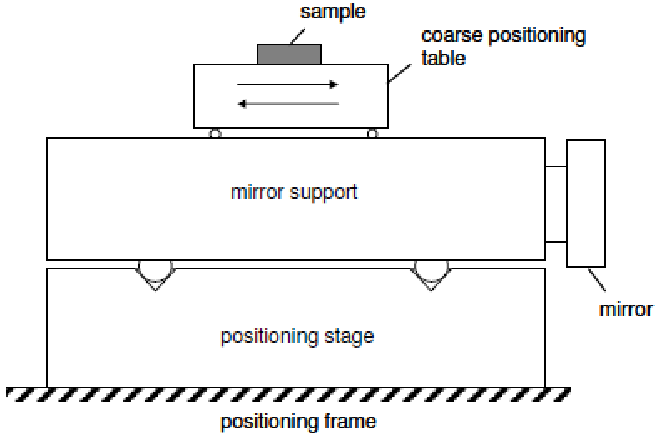
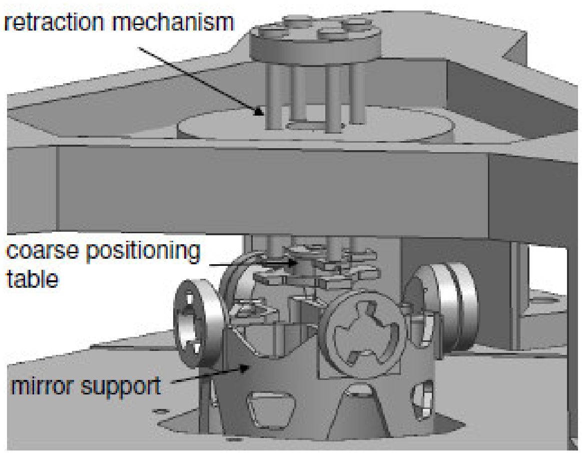
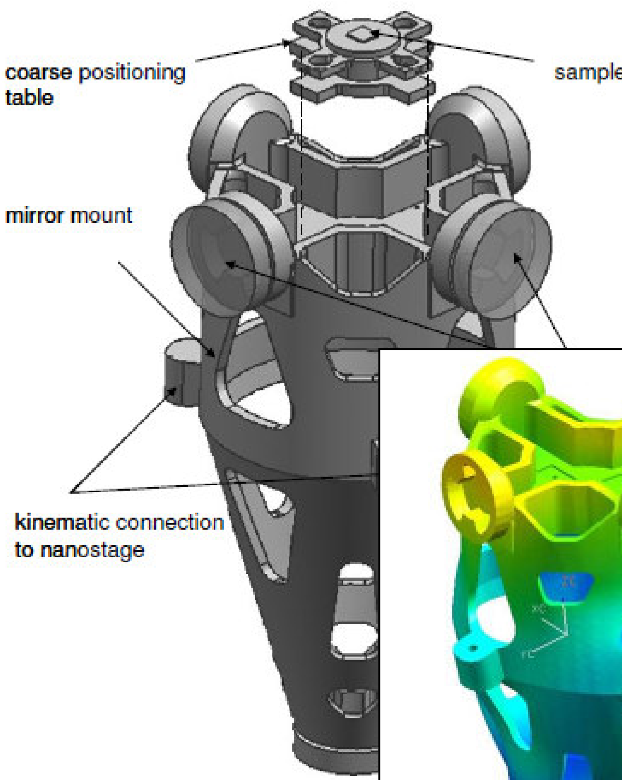
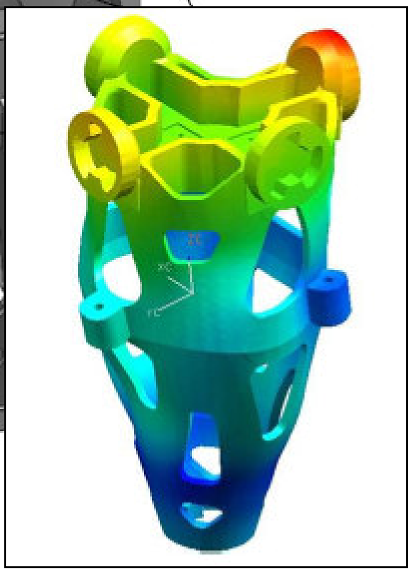
Sample holder





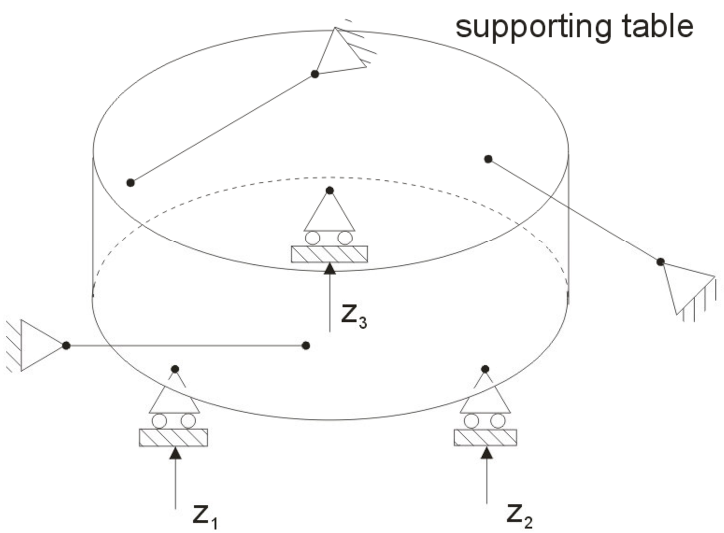




Sample approach mechanism

- Functions
  - Approach sample to probe tip
  - Align sample to frame
- Requirements
  - Mechanical stability
  - Thermal stability
  - Safe approach
  - Sufficient alignment possibilities

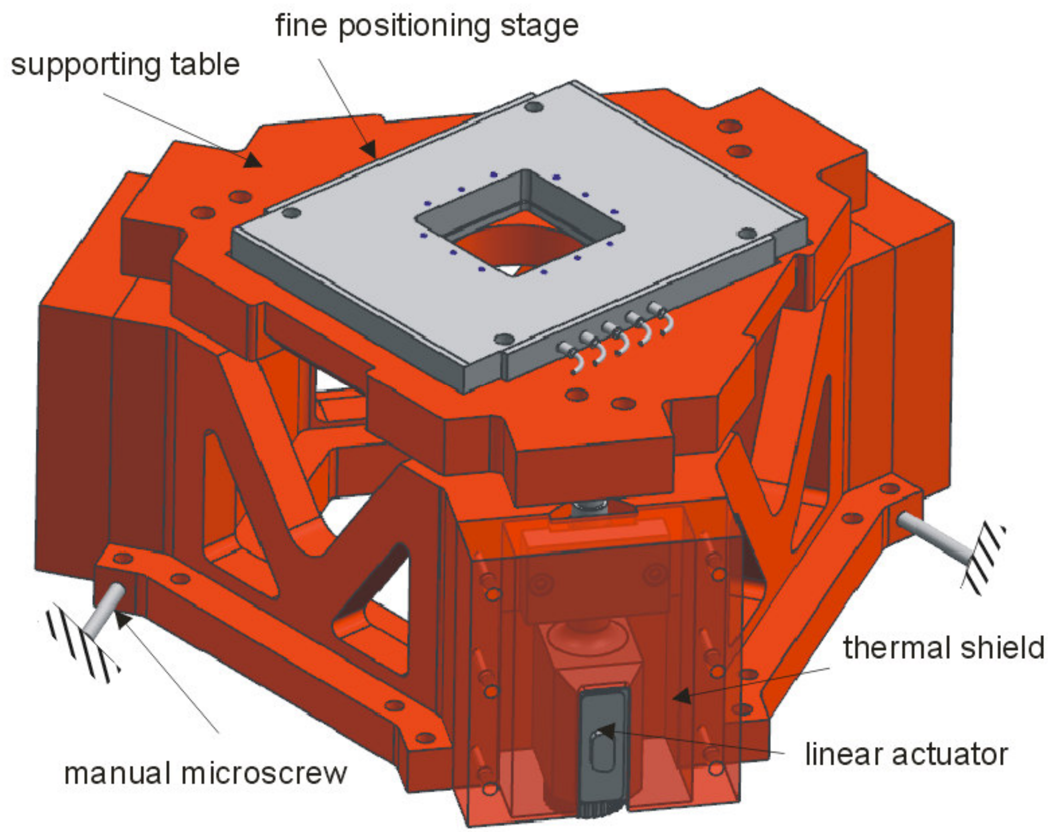
Sample approach mechanism



Properties

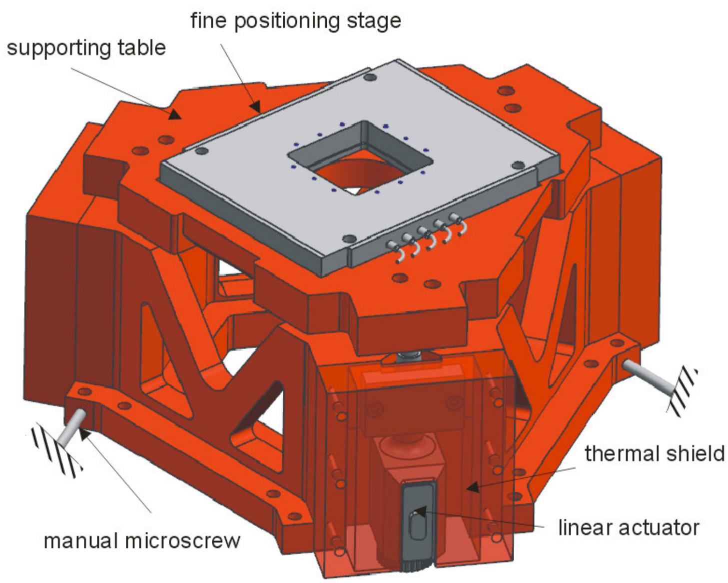
- Compact/integrated design
- Kinematic design
- Careful design of rods
- Thermal design
  - Self-locking actuators
  - Low stress during expansion
  - Good heat conductivity
  - Symmetry
- Alignment possibilties
- Safe approach (2 modes)

Sample approach mechanism

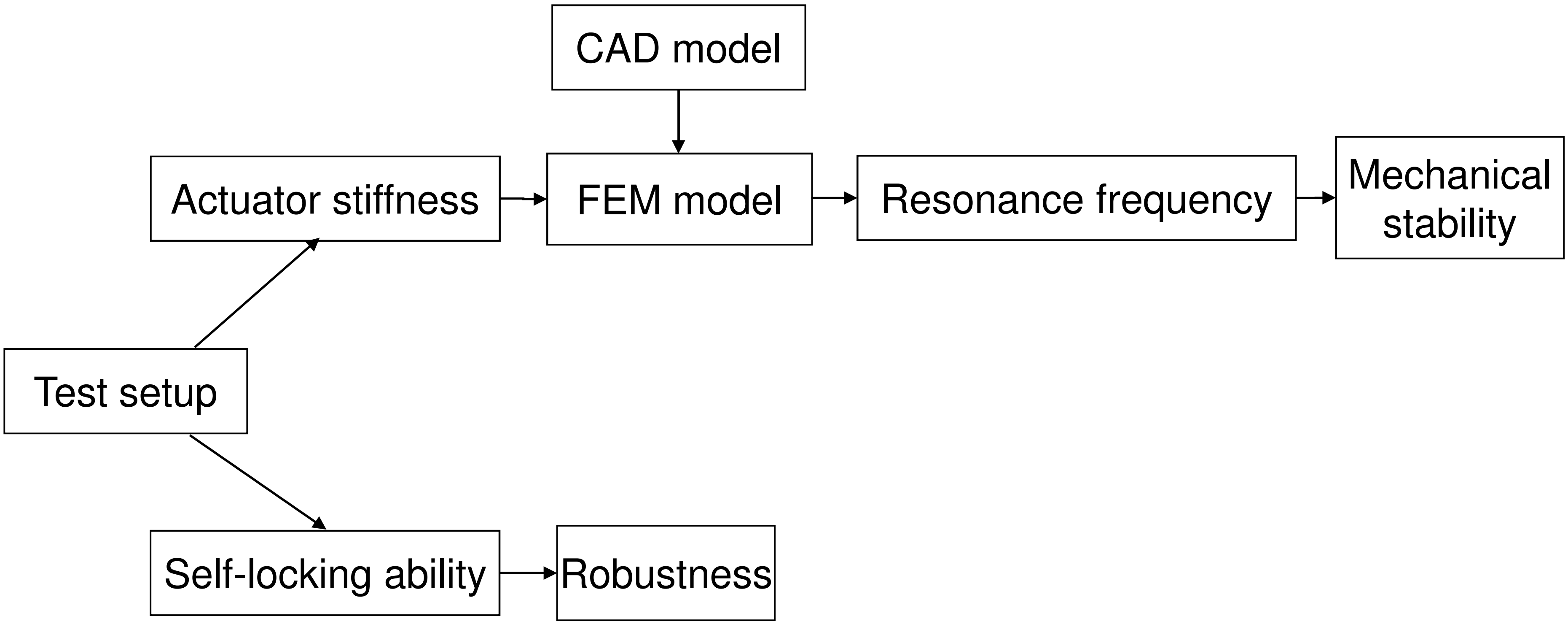


Sample approach mechanism

Specifications	
Mechanical	• automated approach • 1.3 μm resolution • 1 mm stroke
Thermal	• no heat production during scan • fast thermal settling time
Alignment	• alignment accuracy of 45 arcseconds in X- and Y-directions • alignment accuracy of 25 arcseconds in X- and Y-directions • rotation range of 0.4 degrees
Robustness	• safe approach

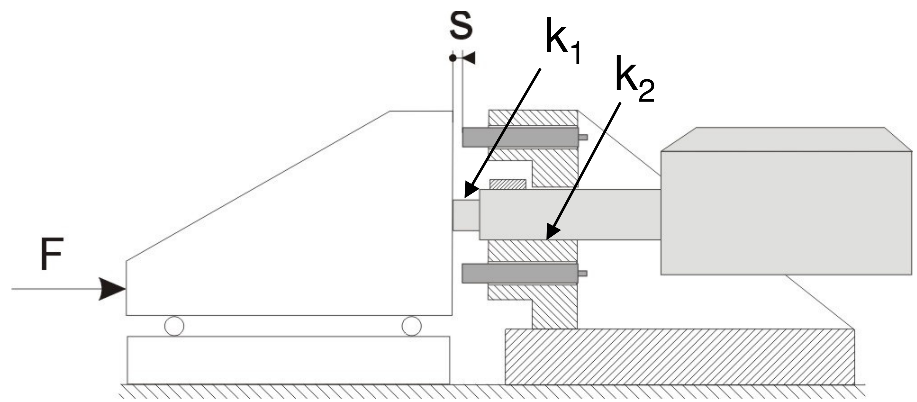


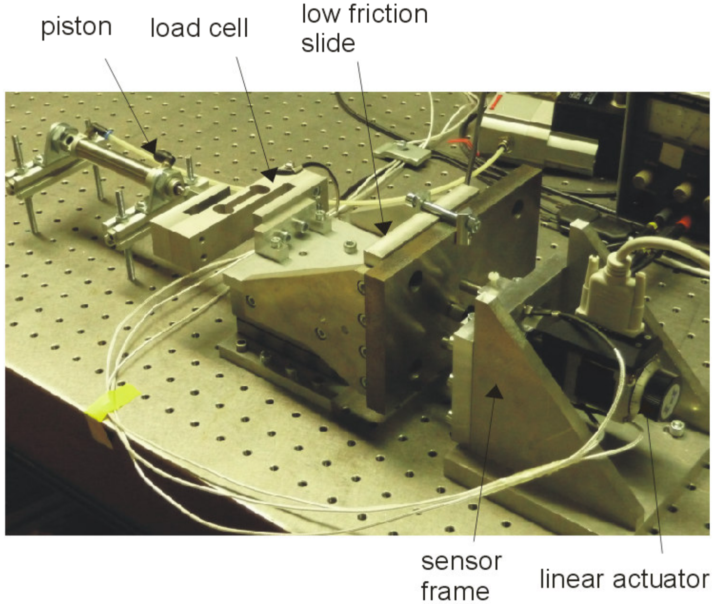
Experiments

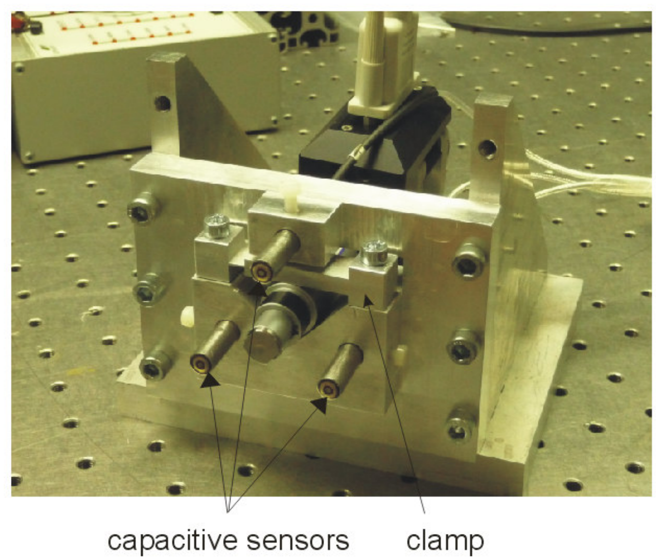


Experiments

Stiffness measurement

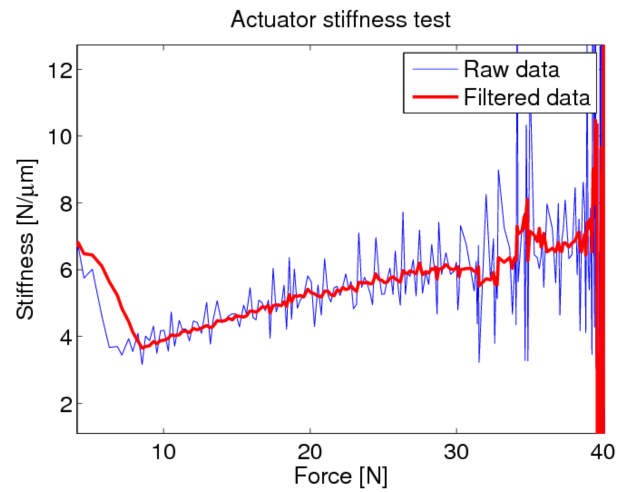






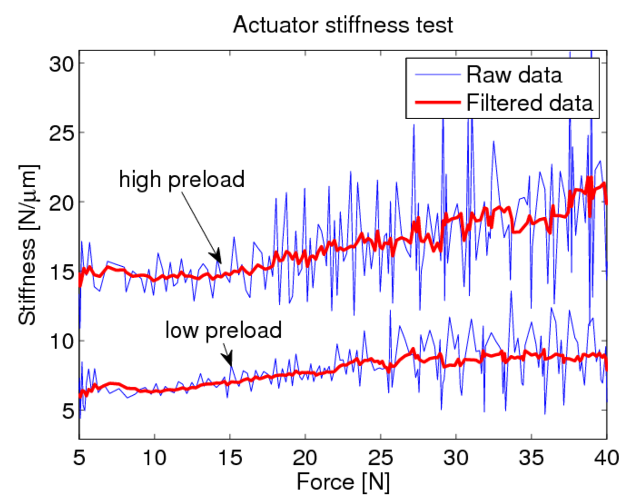
Experiments

<u>**Result for linear actuator**</u>



- Stiffness 4 – 7 N/µm
- Low preload

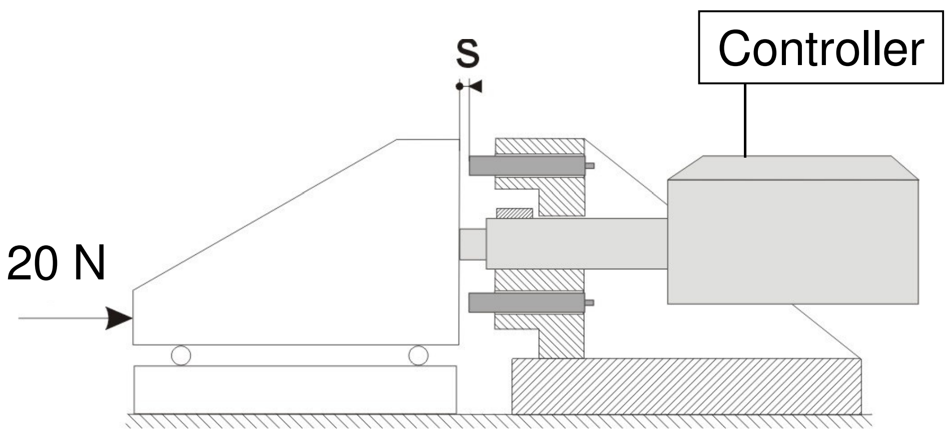
<u>**Result for microscrew**</u>

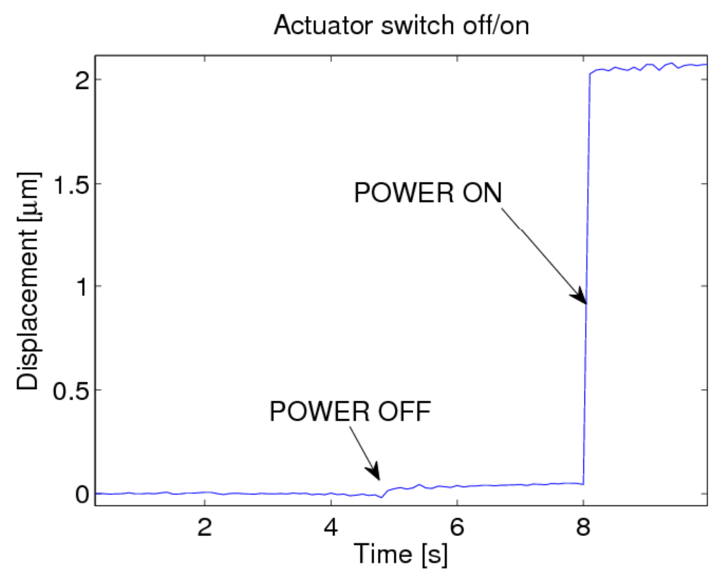


- Higher preload possible
- Same principle
- Low preload: 6 - 9 N/µm
- High preload: 15 – 20 N/µm

Experiments

Self-locking behaviour



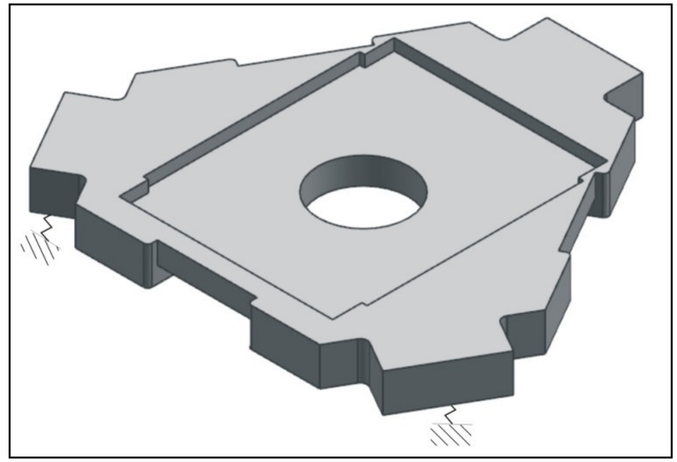


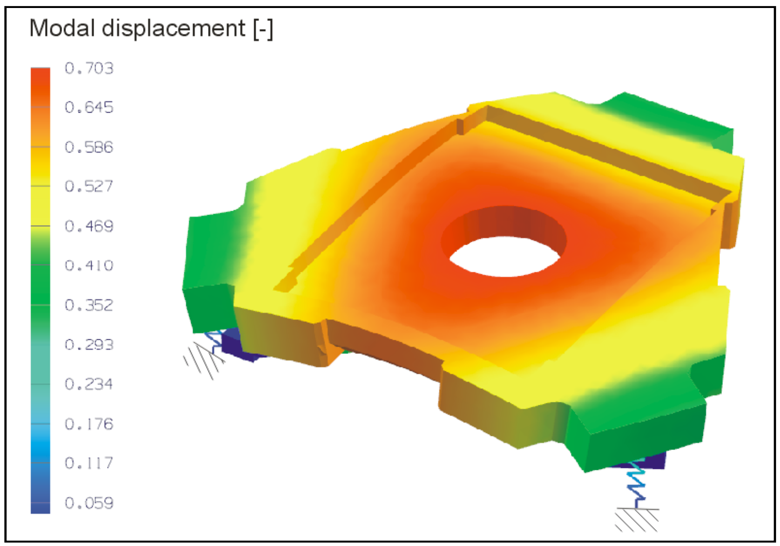
Switch-off: 30 nm
Switch-on: 2 µm

Simulation

FEM model

- Supporting plate
- Actuators: equivalent springs
- Unloaded eigenmodes





Evaluation

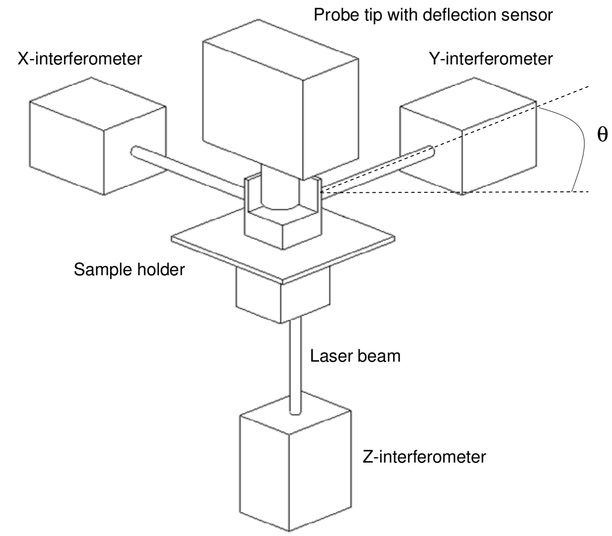
- 395 Hz for 10 N/μm
- High preload: 440 Hz
- Low preload: 285 Hz
- Meets specifications

Alignment procedure

- Cosine error

  $\theta = 200$ arcsec

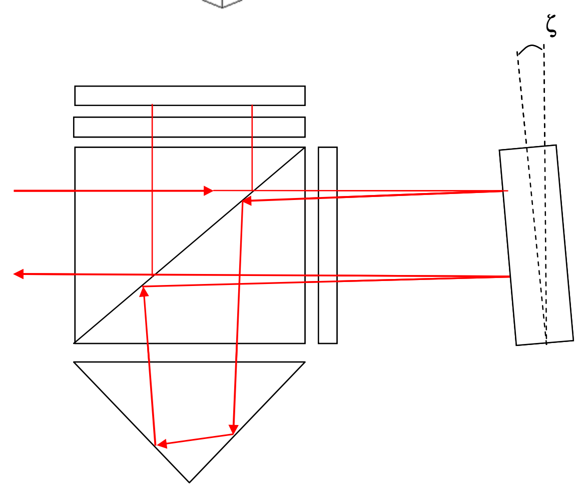
  $U = 0.05$ nm



- Mirror tilt error

  $\theta = 200$ arcsec

  $U = 0.25$ nm



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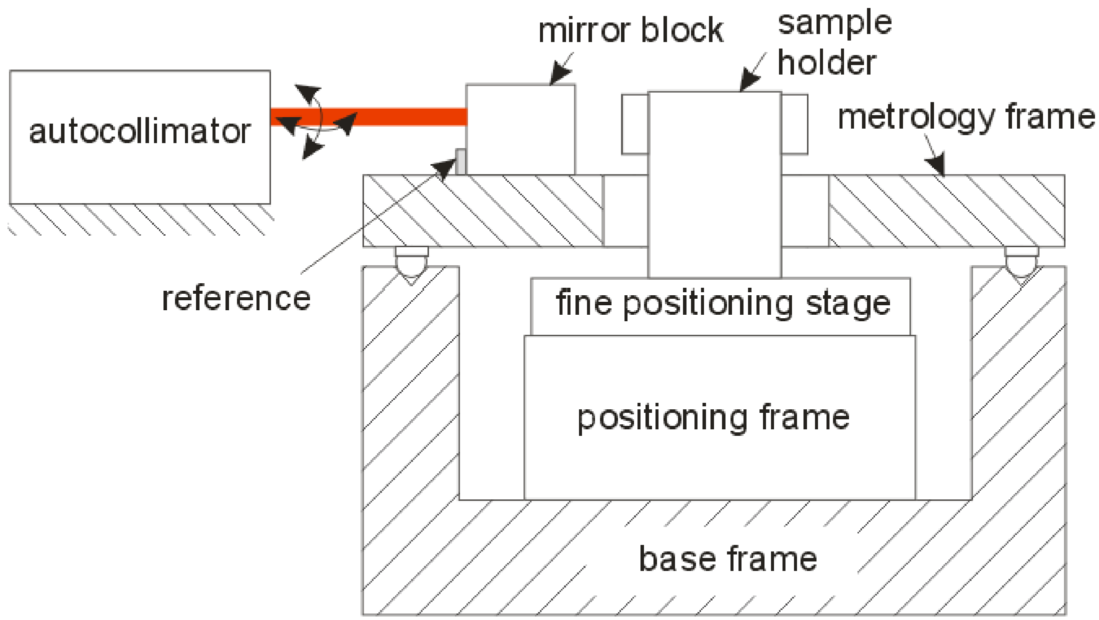

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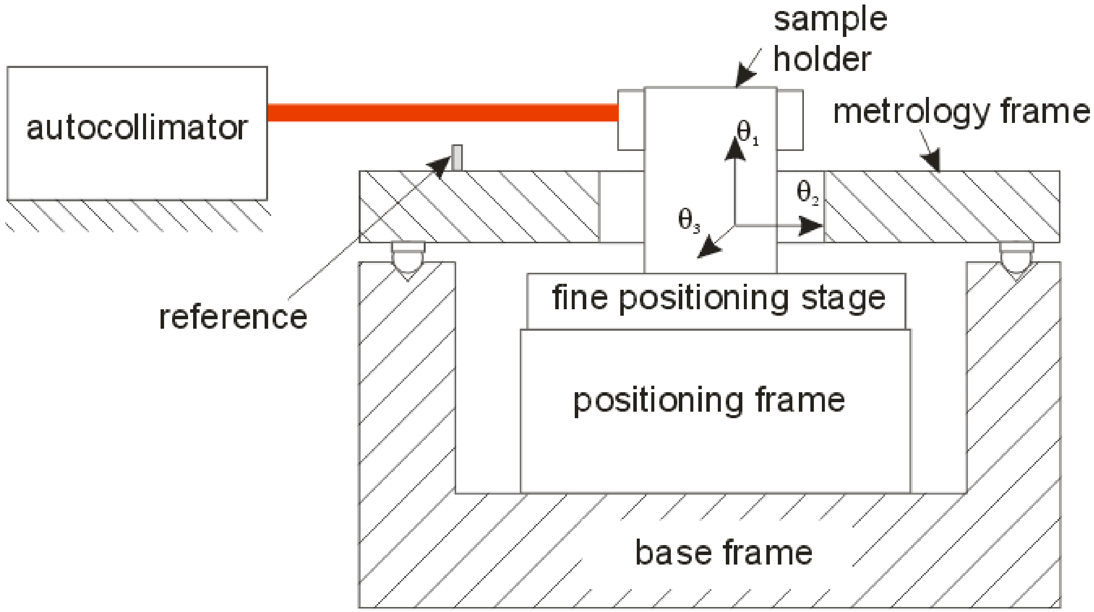

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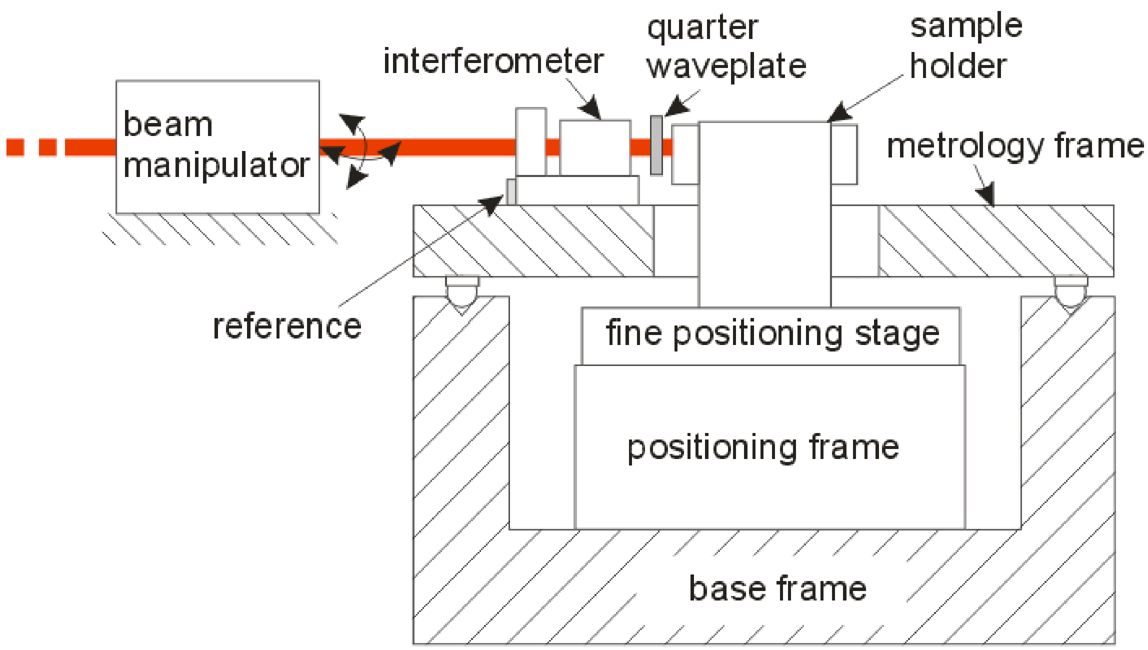

Conclusion

- Design metrological AFM
- Design sample approach mechanism
  - Mechanical properties
  - Thermal properties
  - Alignment possibilities
- Experiments linear actuator
  - Static stiffness
  - Self-locking ability
- Dynamic stiffness of 395 Hz
- Actuator meets design requirements
- Current work
  - Scanhead thermal design
  - Prototype (half November)
  - Production (beginning 2011)